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Testing for Granger causality between energy use and foreign direct investment Inflows in developing countries

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ABSTRACT

Foreign direct investment inflows (FDI) and emissions exhibit a two way relationship. In particular, this research studies the relationship between FDI inflows and emissions from energy use in developing countries. This is done through conducting a Granger causality test on the direction of the relationship between FDI inflows and energy use. For that, a fixed effect panel data model with heterogeneous slopes is used. Heterogeneous slopes specification is selected to account for individual differences within countries. Error correction model is the chosen estimation approach. The empirical results highlight the presence of a two way relationship between FDI inflows and emissions from energy use when testing for short and long run effects jointly. However, this result varies when testing for no long run effect within individual countries. Policy implications for developing countries are also given.

Contents

1. Introduction

Nowadays, environmental concerns are spreading everywhere in both developed and developing countries. The climate is changing, scarce species are diminishing, many resources are depleting and above all humans′ lives are threatened. In general, this is usually attributed to our consumption and production patterns. However, in particular, foreign direct investment (FDI), trade and energy use are usually accused of increasing pollution and environmental degradation.

FDI can increase pollution and environmental degradation when it is concentrated in polluting industries. The pollution havens hypothesis, for example, assumes that stringent environmental laws in developed countries will push polluting industries away from developed countries in the form of FDI outflows [1]. At the same time, lax environmental laws in developing countries will attract polluting industries via FDI inflows. This is magnified with trade liberalization and free movement of capital. Also, trade

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can harm the environment. This may happen, for example, if the traded good damages the environment such as trading in illicit drugs, radioactive wastes, scarce species and prohibited goods.

Furthermore, energy use may result in increasing polluting emissions. According to the World development indicators, energy use is defined as using primary energy before changing to other end-use fuels [2]. This is calculated by adding local production to imports and stock changes and subtracting from them exports and fuels used in international transportation. Accordingly, energy consumption is considered in this definition. Primary energy can be classified into renewable and non renewable sources. Renewable energy sources include solar energy, wind energy, falling and tidal energy, biomass sources and geothermal energy. On the other hand, non renewable energy sources are oil, coal, natural gas and natural uranium. Environmentalists are more concerned with the use of non renewable energy sources. This is because of polluting emissions such as carbon dioxide, nitrogen oxide, or sulfur oxides associated with this process. In contrast, renewable energy sources are environmental friendly and are often labeled as 'clean energy' sources due to releasing less emissions. For instance, to generate electricity from fossil fuels, natural gas releases between 0.6–2 pounds of carbon dioxide equivalent per kilowatt-hour (CO_2E/kWh), while coal releases between 1.4 and 3.6 pounds of CO_2E/kWh [3]. In contrast to this, renewable energy sources produce lower levels of carbon dioxide emissions so that the corresponding figures for wind, solar, geothermal and hydroelectric are between 0.02–0.04, 0.07–0.2, 0.1–0.2 and 0.1–0.5 pounds of CO_2E/kWh respectively [3]. However, emissions from biomass can be higher if compared to other renewable energy sources depending on the resource and the applied technique.

It is true that the use of clean energy is increasing over time but still fossil fuels remain the major source of energy worldwide [4]. For that, energy use can be used as a proxy measure for pollution emissions. However, if patterns of energy consumption change in the future, this argument will no longer be true.

There is a two way relationship between FDI inflows and emissions from energy use. This is because high emissions from energy use, which are a result of lax environmental laws in a country, attract polluting FDI inflows. On the other hand, FDI inflows can affect emissions from energy use. This may happen when FDI inflows increase energy consumption in a country and hence, may lead to more polluting emissions. It would be interesting also to consider the effect of FDI inflows on pollution emissions from energy use when these FDI inflows use environmental friendly techniques in production.

For that, this paper focuses on studying the relationship between FDI inflows and emissions from energy use. This is done through conducting a Granger causality test on the direction of the relationship between FDI inflows and energy use in developing countries. In general, Granger causality test measures the direction of the relationship between two or more variables. Granger measures causality between two variables X and Y through testing how much of the current values of Y are explained by preceding values of Y and whether the insertion of lagged values of X improves the explanation [5].

The rest of the paper is organized as follows: Section 2 describes recent trends of FDI and energy use. Section 3 provides a quick theoretical background with empirical evidences. Section 4 includes the empirical analysis. Section 5 presents the empirical results. Finally, Section 6 concludes and suggests policy implications for developing countries.

2. Recent trends of FDI and energy use

The scale of FDI has amplified quickly during the period 1980–2000. As reported by Fredriksson, nominal FDI inflows worldwide enlarged by 18% per year during 1987–1997 [6]. This result is confirmed by the figures of the Organization for Economic Co-operation and Development (OECD) of both FDI inflows and outflows for OECD countries [7]. Fig. 1 shows the increase in FDI inflows from 1995–2009 by region [8].

Nevertheless, FDI composition and the relative importance of its determinants varied across time [9]. For example, FDI was mostly in the primary sector and natural resources were the most effective determinant of FDI in the 50s [10,11]. Since the 60s, FDI was more going to the industrial sector with a shrinkage in natural resource importance. Escaping trade barriers is a likely explanation for variations in FDI flows. Also, there are other sources of attraction to FDI investors such as market size and economic growth [11].

Since the 80s FDI inflows were more towards the services and technology based manufacturing. For example, FDI inflows in the services sector accounted for 60% of FDI inflows in 1990 [12]. The increase in importance of the services sector is evident in the case of FDI inflows in developing countries. However, still the petroleum sector, construction, chemicals production and transportation are the main receivers of FDI inflows in developing countries [13]. Accordingly, polluting industries are still concentrated in developing countries through FDI. Table 1 illustrates FDI inflows to developing countries by sector [14].

The share of FDI inflows to developing countries has increased from 25% of world FDI inflows in 1980–84 to 40% in 1994–96 [9]. Among developing countries, China has been the chief beneficiary of FDI inflows since 1992. Not only this, but also China is the second largest receiver in the world after US. China accounts for 35% of FDI flows to developing countries with a $33 billion of FDI yearly from 1993–96. Second after China are South, East and Southeast Asia (excluding China) and Latin America and the Caribbean each constituting 30% of FDI flows to developing countries. FDI inflows to Latin America and the Caribbean peaked at $39 billion annually in 1994–96. Nevertheless, since then their share has been declining opposite to its comparable South, East and Southeast Asia whose share is increasing. Lastly, in absolute terms FDI inflows to Africa enlarged from an annual average of $800 million in 1975–80 to $4.5

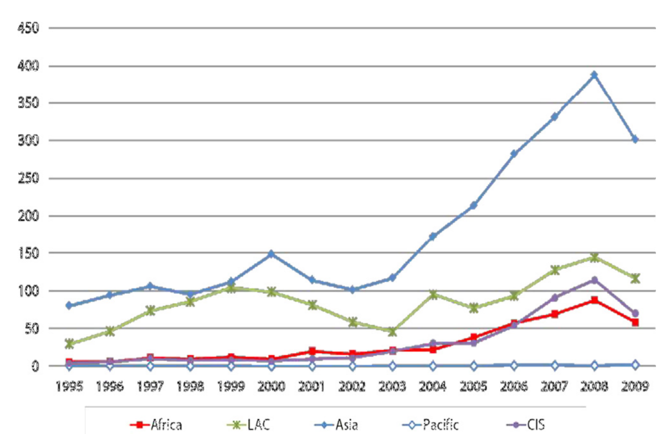


Fig. 1. FDI Inflows by Region (1995–2009) US$ Billions.
Source: Calculated using data from UNCTAD World Investment Report [8].

Table 1
FDI inflows to developing countries by sector (US$ Billions).
Source: Calculated using data from UNCTAD, World investment report [14].

Period	Primary	Manufacturing	Services
1989–1991	3.9	16.1	9.3
2005–2007	46.8	121.0	161.4

billion in 1994–96. However, Africa's share of FDI inflows to developing countries has decreased from 11% in1986–90 to only 4.1% in 1994–96. Regarding oil producing countries, their share in FDI inflows to developing countries was reduced from 50% in 1979–81 to only one fifth in 1995–96 [9]. Fig. 2 illustrates FDI inflows within developing countries.

Recently, there has been a slowdown in the growth figures of global FDI. Weak economic growth, deficiencies in stock markets and institutional obstacles are likely factors for this slowdown [15]. In addition, the Arab Spring since 2011 with its political and economic instability affected negatively FDI inflows to the Middle East. In the past, North Africa was the dominant recipient of FDI inflows to Africa. In 2011, FDI inflows to the continent were cut by 50% to reach $7.69 billion with negligible flows to Egypt and Libya [13].

According to the International Energy Outlook of 2011, World energy consumption is increasing over time [16]. Fig. 3 shows this increase from 1990 till 2008. In addition, projections from 2008 till 2035 are also given. It is true that the downturn of 2008-2009 slowed down energy consumption. However, with the recovery from this recession, many countries continued their increase in energy use. In 2008, energy use in non OECD countries was 7% higher than that in OECD countries. India and China were the least affected countries by the world recession. They continued growth in both GDP and energy consumption. From 1990 onwards, the share of both countries in world energy use increased from 10% in 1990 to 21% in 2008. Not only this, but their economies enlarged by 12.4% for China and 6.9% for India in 2009. This is opposite to the case of the US whose energy consumption decreased by 5.3% in 2009 [16]. In addition, China surpassed US for the first time in energy consumption to be the leading country in energy consumption worldwide in 2009. Fig. 4 shows US, India and China energy consumption.

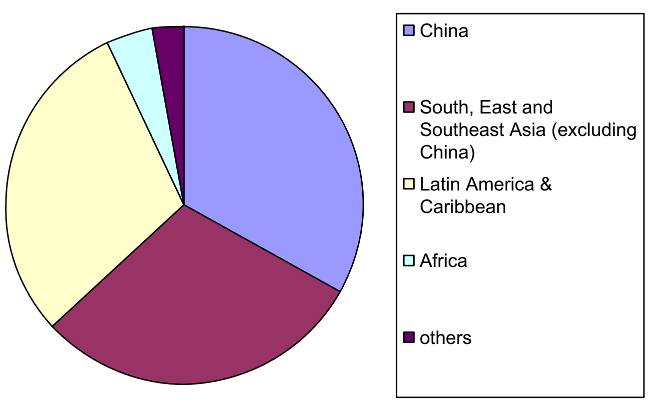


Fig. 2. FDI Inflows in Developing Countries in 1994–96.
Source: Calculated from data given by Noorbakhsh et al. [9].

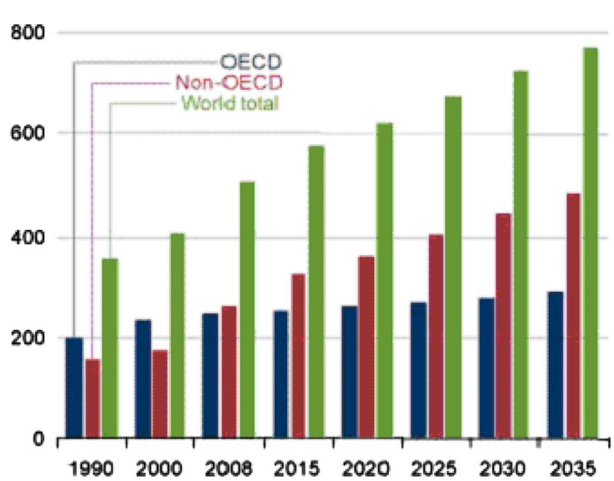


Fig. 3. World Energy Consumption 1990–2035 (quadrillion Btu).
Source: International Energy Outlook 2011.

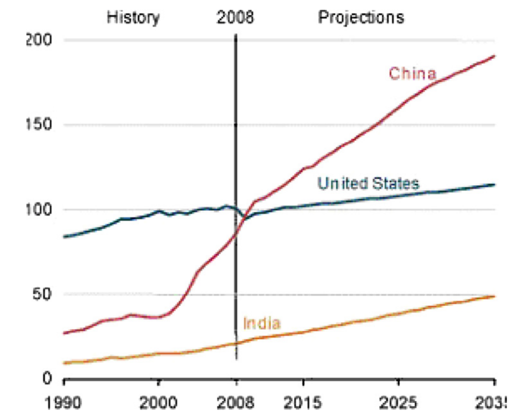


Fig. 4. Energy Consumption in US, China and India 1990–2035 (quadrillion Btu).
Source: International Energy Outlook 2011.

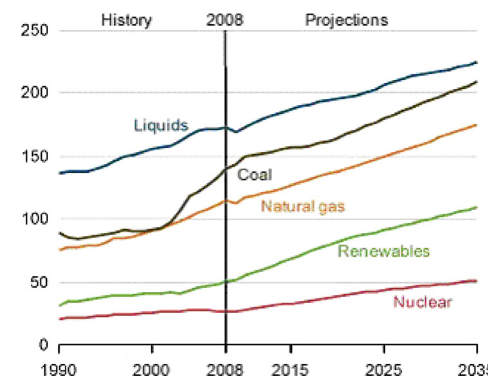


Fig. 5. World Energy Consumption by Fuel, 1990–2035 (quadrillion Btu).
Source: International Energy Outlook 2011.

According to Fig. 5, it is very evident that petroleum and other liquid fuels are the highest in world energy consumption from 1990–2008. They are followed by coal, natural gas, renewables and at the end comes nuclear energy. This justifies the environmental concerns related to polluting emissions evolving from energy use. However, it is expected from 2008–2035 that petroleum and liquids will be the slowest growing source of energy in the world. The reason behind this can be attributed to their cost. On the other hand, renewables are expected to be the fastest in growth. The spread of environmental awareness can be one of the causes that may lead to this result.

To measure the effect of energy consumption on emissions, Fig. 6 shows world primary energy consumption and CO_2 emissions from energy combustion in the period of 1970–2007 [17].

After looking at recent trends of FDI, energy use and emissions released from energy use in developing countries and worldwide, it is clear that they are growing over time. Hence, it would be interesting to study their relationship. To stand on a solid ground, it is appropriate first to have a quick review of the literature in comparison to empirical evidences.

3. Theoratical background and empirical evidences

The theory of FDI states that FDI inflows are attracted to countries that have relatively higher rates of return [18]. There

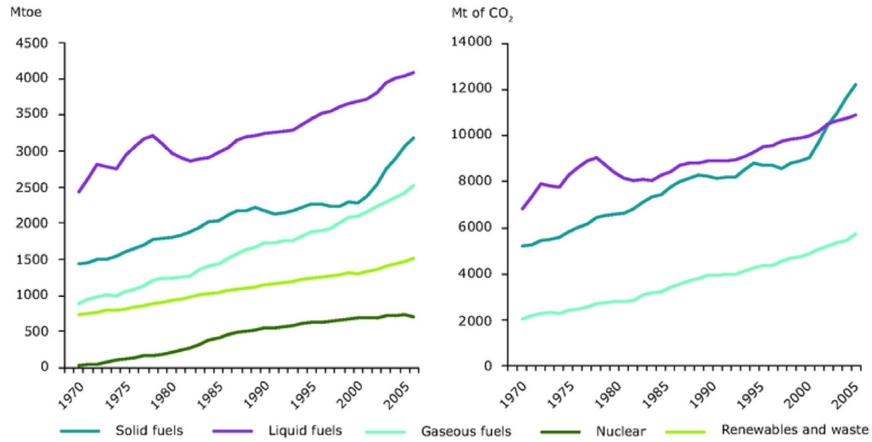


Fig. 6. World Primary Energy Consumption and CO_2 Emissions from Energy Combustion 1970—2007.
Source: European Environment Agency, 2011.

are classical determinants of FDI inflows in the literature which include macroeconomic stability, market size, trade openness, labor cost and energy availability. Recently, environmental policies have been considered as another factor that affects FDI inflows.

3.1. *FDI-environment relationship*

In general there are two schools of thoughts that explain FDI-environment relationship, namely, the classical trade perspective of comparative advantage and the neo-technology trade perspective [15]. According to the classical trade perspective of comparative advantage, environment is treated as another factor of production in which stringent environmental laws increase production costs. Accordingly, developed countries will not specialize in polluting industry due to the cost incurred. On the other hand, developing countries with lax environmental laws will specialize in polluting industries due to relatively lower cost. Within this context, the pollution havens hypothesis states that with free trade and movement of capital, stringent environmental laws in developed countries will push polluting industries away from developed countries in the form of FDI to developing countries [1]. At the same time, lax environmental laws in developing countries will attract polluting industries via FDI to these countries. One empirical result of this hypothesis is that there is a positive relationship between FDI inflows and emissions in developing countries.

Opposite to this school of thought, the neo-technology trade perspective believes that there is a positive relationship between FDI and the environment. For instance, the pollution haloes hypothesis states that FDI could have a positive impact on environment through the transfer of environmental friendly techniques of production from developed countries to developing countries that rely on environmental damaging techniques. According to the OECD, environmental friendly techniques are transferred through better technologies that aim at higher environmental standards or even through management techniques in large firms or multinational corporations [19]. Also, most of private firms that invest in non OECD countries have managerial efficiencies and are more accountable which in turn decreases waste and pollution [19]. Accordingly, the empirical result of the pollution haloes hypothesis states that there is a negative relationship between FDI inflows and emissions in developing countries.

Hence, it can be deduced from this discussion that the effect of FDI on emissions is a debatable issue. What interests us here is that theoretically there is a relationship between FDI inflows and emissions evolved from energy use. However, the nature of relationship is still indistinct. This explains one direction of the relationship which is from FDI to the environment.

However, theoretically speaking, the environment affects FDI as well. This happens when lack of environmental concerns proxied by high pollution emissions attract polluting FDI inflows. This argument is also true for emissions from energy use. Likewise, strong environmental concerns reflected via stringent environmental laws result in decreasing emissions which in turn will push polluting FDI away. Hence, there is a two way relationship between FDI and emissions from energy use.

One cannot study energy use without extending the discussion further to include two important concepts, namely energy intensity and energy efficiency. Energy intensity is a concept that is very much related to energy use and energy efficiency. Energy intensity is defined as the amount of energy needed (energy use) per unit of output [20]. Hence, low intensity means that less energy is required to generate a unit of output. Accordingly, lower energy intensity is preferred. However, energy efficiency is the reciprocal of energy intensity. Energy efficiency is defined as the quantity of output that can be achieved per unit of energy [20].

It is noteworthy to mention that a decrease in energy intensity can be used as a proxy for development in energy efficiency. This is true if energy intensity is studied using disaggregated data to make the analysis meaningful. Also, independent and behavioral variables should be isolated and considered [20]. This is because sometimes changes in energy use would result in changes in energy intensity but have no indication whatsoever for changes in energy efficiency. This may happen when changes in energy use are mainly due to structural, behavioral or other uncontrolled exogenous variables such as the weather. For instance, a movement towards a less energy intensive industry indicates a reduction in energy intensity but does not imply by any means an improvement in energy efficiency. Following the same logic, using less heaters in winter when the climate is getting warmer or using more heaters when you grow old as you have a stronger feeling of cold indicate other cases where changes in energy use result in changes in energy intensity but not necessarily show a change in energy efficiency [20]. Understanding the relationship between energy use, energy intensity and energy efficiency is a precondition to design appropriate policies for the future. That will be explained further in Section 6.

On the empirical level, the debate on FDI-environment relationship is still present. For example, Levinson through reviewing the literature showed that after 20 years of research the evidence to support the pollution havens hypothesis is weak [21]. In line with that, Copeland and Taylor argued that there can be a pollution havens effect and not a hypothesis [22]. In addition,

the OECD showed that most polluting FDI from developed countries are directed to developed countries as well [23]. Also, Acharyya studied the effects of FDI growth and the FDI-induced growth on carbon dioxide emissions in India [24]. The results of this study showed that the pollution havens hypothesis was not capable of explaining the increase in FDI in 1990s. Nevertheless, the results may vary if other pollutants are considered.

Opposite to that, Kolstad and Xing showed evidence for the pollution havens hypothesis [25]. Also, Co et al. showed that loose environmental laws attract polluting FDI inflows [26]. Furthermore, Smarzynska and Wei showed that there is a support for the pollution havens hypothesis when the country environmental standard is proxied by its participation in international environmental agreements [27]. Mihci et al. showed that there is a positive relationship between FDI outflows and stringency of environmental laws in developed countries [15]. Aliyu confirmed this result in his research using disaggregated data [1]. Perkins and Neumayer indicated in their research that neither transnational linkages via exports nor FDI inflows influence local pollution efficiency [28]. Nevertheless, import links with more pollution efficient countries improve these pollutants′ emissions due to spillover effects.

Furthermore, Balezentis et al. studied energy intensity trends in Lithuania on the aggregate and sectoral levels from 1995–2009 [29]. They used the Logarithmic Mean Divisia Index (LMDI) in their decomposition analysis to identify and to measure the factors affecting energy consumption and to provide a suitable base for designing future policies to improve energy efficiency [29]. Their results showed that the structure of energy consumption has varied throughout the studied period. In addition, the results of the additive and multiplicative LMDI through a period-wise and chaining decomposition highlighted that with the exception of the transportation sector, all other sectors resulted in the decline in the need for energy. The decline in all other sectors resulted in the offset of the increase in the transportation sector and then resulted in a decrease in total energy consumption. In addition, there was a rise in energy demand due to economic growth which was partially eliminated by energy intensity effect. Furthermore, the results indicated that the largest intensity effect was found in the services and households sectors followed by the industry and construction sectors. This very last result is of crucial importance as it highlights the need for designing suitable policies to promote energy saving techniques within these two sectors to reduce energy intensity. Other policy implications were also given, such as the importance of having efficient policies to improve energy use, energy intensity and efficiency in the transportation sector in particular. This can be achieved through financing the use of electric vehicles, developing roads and infrastructure and providing better public transportation services [29].

Another research by Brizga et al. investigated the cause for a decline in carbon dioxide emissions for the countries of the former Soviet Union (FSU) in spite its increase globally [30]. This was studied on a country basis level through using a disaggregated version of the IPAT index decomposition analysis in which the effects of changes of energy intensity, affluence, industrialization, energy mix, carbon intensity and population on carbon dioxide emissions were investigated. The results showed that the effects of these variables vary according to the stage of development a country is in. For instance, in expansion time, the increase in emissions as a result of affluences was partially met by declining energy intensity. However, in recessions, the decrease in emissions was a result of a decrease in both affluence and fossil fuels share. Furthermore, neither the degree nor the persistence of affluence, energy intensity, population and industrialization were uniform across the FSU countries. This is vital to acknowledge in designing appropriate policies regarding carbon dioxide emissions and energy use. In addition, a linear regression analysis was conducted to study the effect of all previously mentioned explanatory variables on carbon dioxide emissions in 15 of the FSU countries during the period of 1990–2010. The results showed that all explanatory variables coefficients were positive and significant with the exception of industrialization coefficient that was insignificant at 5% level in recession period. The results also showed that changes in carbon dioxide emissions are influenced the most by affluence and energy intensity throughout the sample and in recession period. However, in expansion time the relative importance of affluences decreased while that of carbon intensity, industrialization, and energy mix increased [30].

Also, Ang and Zhang in their research studied energy related carbon dioxide emissions in various regions of the world [31]. They deduced that lower aggregate carbon dioxide emissions in FSU than OECD countries could be attributed to lower income and population. However, higher energy intensity in FSU countries altered much of this result.

On the other hand, Davis and Caldeira showed that carbon intensity of GDP is highest in Belarus, Russia, Ukraine and Kazakhstan [32]. This is due to high energy intensity especially with the dominance of heavy industries and energy products or even as a result of economic problems that accompanied collapse of the Soviet Union [32].

Hübler and Keller studied the effect of FDI inflows on energy intensities of developing countries on a macro level [33]. An OLS estimation was used for a sample of 60 countries during 1975–2004. The results did not verify the hypothesis that aggregate FDI inflows decrease energy intensity. However, there were energy efficiency gains associated with foreign development aid.

After this theoretical and empirical review, it is apparent that the controversy in FDI-environment relationship is still present. For that, it is essential to study their relationship further to be able to have a better understanding. One way of doing so is to conduct a Granger causality test on the direction of the relationship between FDI inflows and emissions from energy use.

3.2. *Granger causality test*

Granger measures causality between two variables X and Y through testing how much of the current values of Y are explained by preceding values of Y and whether the insertion of lagged values of X improves the explanation [5]. The F-statistic is used to test for the joint hypothesis that the regression coefficients $\beta_1=\beta_2=\beta_3 \ \ldots=\beta_k=0$. Hence, the null hypothesis of X does not Granger-cause Y is tested. Granger causality test is generally conducted to examine a two-way relationship between two variables in two different regressions. In particular, the hypothesis of X does not Granger-cause Y is tested in the first regression in contrast to the hypothesis of Y does not Granger-cause X in the second regression.

On the empirical level, Hoffmann et al. examined Granger causality between FDI and environment applying VAR technique in a panel data model [34]. Their conclusion was that in low-income countries carbon dioxide emissions Granger-cause FDI inflows, whereas in middle income countries FDI inflows Granger-cause carbon dioxide emissions. Furthermore, Granger causality in high income countries was not apparent.

Lee tested for Granger causality between FDI, pollution and economic growth in Malaysia in the period 1970–2000 within an ECM [35]. His conclusion was that FDI and carbon dioxide Granger-cause GDP, whereas FDI only Granger-cause carbon dioxide in the short run. Nevertheless, the results indicated that GDP Granger-cause FDI in the long run.

Furthermore, Pao and Tsai studied the effect of FDI on CO_2 emissions using a panel cointegration technique [36]. The countries

studied were Russia, Brazil, India and China in the period ranging from 1980–2007. Their results indicated that there is a positive relationship between FDI inflows and CO_2 emissions. Also, they conducted a Granger causality test that showed that FDI and Co_2 emissions exhibit a two way relationship. Also, there is a Granger Causality between output-emissions and output-energy consumption that runs in both directions. Finally, the results indicated that energy consumption Granger Causes emissions.

Wang et al. examined the relationship between energy consumption, economic growth and FDI in China in a multivariate VAR model [37]. This was studied over the period of 1985–2010 depending on Shanghai data. The results indicated that GDP Granger Causes energy use and FDI and that energy consumption Granger Causes FDI. In addition, the analysis showed that FDI has a positive effect on energy savings which highlights designing appropriate policies to promote and direct FDI [37].

Close to this, another study by Kuo et al. tested for Granger Causality between economic growth, FDI and energy consumption in China from 1978–2010 [38]. The results indicated that GDP Granger Causes energy consumption whereas there is Granger causality between FDI and energy consumption that runs in both directions. The authors highlighted the importance of studying the pros and cons of FDI and strong enforcement environmental protection policies [38]. Longer time period could be a possible reason for discrepancies in results between this research and that of Wang et al. [37].

Finally, Chandran and Tang in their study examined the effect of the transportation sector's energy consumption and FDI on carbon dioxide emissions for the ASEAN-5 economies through the use of Cointegration technique and Granger Causality test [39]. Their results indicated the existence of a two way relationship between carbon dioxide emissions and economic growth in Indonesia and Thailand in the long run. However, there is a unidirectional causality in Malaysia from GDP to carbon dioxide. Furthermore, a two way relationship between FDI, carbon dioxide emissions and transport energy consumption in Thailand and Malaysia is found. Accordingly, the authors suggested the control of energy consumption in the transportation sector to reduce carbon dioxide emissions [39].

4. The empirical model

The empirical model studies the relationship between FDI inflows and emissions from energy use in developing countries. This is done through conducting Granger causality test using error correction approach (ECM). This research uses a panel data model. The data set is for 23 developing countries and covers the period from 1971–2010 for which data is available.[1] All data are collected from the World Development Indicators (WDI) database of the World Bank [2]. Missing data were calculated through the use of linear interpolation.

4.1. The econometric approach

Marrocu et al., Zhang and Felmingham and Lee studied Granger causality tests using ECM approach [40,41,35]. ECM is a suitable modeling approach as it minimizes spurious results and studies long run/short run relationships. In addition, in ECM no information is ignored due to the inclusion of the disequilibrium error term. Furthermore, ECM allows for the use of OLS in estimation. To do so, the first step is to examine stationarity of the variables. The second step is to construct an ECM in both directions. This is to test for the presence of a short run adjustment towards long run equilibrium in one or two directions. The stationarity test is conducted via Augmented Dicky Fuller (ADF) and Phillips Perron (PP) tests. The causality test contains two ECMs as follows.

$$\Delta Y_{i,t} = lagged(\Delta Y_{i,t-1}, \Delta X_{i,t-1}) - \lambda_1 e_{1i,t-1} + \in_{1i,t} \quad (1)$$

$$\Delta X_{i,t} = lagged(\Delta X_{i,t-1}, \Delta Y_{i,t-1}) - \lambda_2 e_{2i,t-1} + \in_{2i,t} \quad (2)$$

In Eqs. (1) and (2), λ is the coefficient of the disequilibrium error term, $e_{i,t-1}$ is the lagged residual taken from the estimation of the long-run relationship and it represents the disequilibrium error term. There are two possible channels for Granger Causality within an ECM.[2] The first channel is linked to the adjustment of the variables to the long run equilibrium represented by λ, whereas the second channel is linked to the short run reaction of one variable. Granger Causality tests are misspecified if the first channel is not taken into account. A two-way relationship exists between X and Y if λ_1 and λ_2 are significant. However, a one way relationship exists when only one of them is significant. Furthermore, the exclusion of the first channel occurs when both λ_1 and λ_2 are insignificant. Yet, Granger causality may still be detected from the second channel although it was not evident in the first one. This shows a short run interaction between the two variables. In such a condition, standard Granger causality tests are used [42].

4.2. The choice of variables

FDI is foreign direct investment inflows in developing countries and is measured as net foreign direct investment inflows as a percentage of GDP. FDI inflows are usually preferred than FDI stocks. This is because stocks reflect the total book value of investment by a country at a specific period. Therefore, they could be subject to variations in company accounts or exchange rates ups and downs. On the other hand, flows measure levels of investment over time, usually on an annual basis [43]. In addition, FDI inflows are commonly used by many researchers such as Aliyu, Mihci et al. and Letchumanan and Kodama [1,15,44].

To measure pollution emissions from energy use, the log of energy use measured in kilo tons (Kt) is used. Energy use is an appropriate measure to reflect pollution emissions. This is because after reviewing the trends of energy use in Section 2, it becomes clear that fossil fuels are the highest in consumption. In addition, non renewable energy sources are always associated with polluting emissions such as carbon dioxide, nitrogen oxide, or sulfur oxides. Accordingly, pollution emissions will increase with energy consumption. Hence, energy use can be taken as a proxy measure for pollution. In addition, it was used before by other researchers. For instance, Aliyu in his research work examined the effect of FDI inflows on emissions from energy use, known particulate matters and carbon dioxide [1]. Furthermore, carbon dioxide is widely used to reflect emissions by many researchers and hence, it will be interesting to examine the effect on other sources of emissions such as that from energy use.

4.3. Estimation

To test for Granger causality between FDI and emissions from energy use in developing countries, consider a fixed effect panel data model with heterogeneous slopes. Heterogeneous slopes specification is used to account for individual differences within countries. To conduct the test through ECM, stationarity of the

[1] The list of countries includes Algeria, Bolivia, Cameroon, Chile, China, Colombia, Costa Rica, Ecuador, Egypt, Guatemala, Honduras, India, Indonesia, Iran, Mexico, Morocco, Nepal, Pakistan, Philippines, South Africa, Sri Lanka, Tunisia and Venezuela.

[2] See Zhang and Felmingham [41] and Marrocu et al. [40].

variables is examined first. ADF and PP unit-root tests results for FDI inflows and emissions from energy use are presented in the appendix. The results showed that FDI inflows are I(0), while energy use is I(1). The next step is to run two ECM estimations. The causality test for FDI inflows and emissions from energy use in developing countries is examined in two ECMs as follows.

$$\Delta FDI_{i,t} = (T_i, lagged(\Delta FDI_{i,t-1}, \Delta ENG_{i,t-1})) - \lambda_1 e_{1i,t-1} + \in_{1i,t} \quad (3)$$

$$\Delta ENG_{i,t} = (T_i, lagged(\Delta ENG_{i,t-1}, \Delta FDI_{i,t-1})) - \lambda_2 e_{2i,t-1} + \in_{2i,t} \quad (4)$$

where FDI is foreign direct investment inflows in developing countries, ENG is log of energy use in developing countries measured in kilo tons which reflects emissions, T is a trend term to account for technical progress effect, λ is the coefficient of the disequilibrium error term, $e_{i,t-1}$ is the lagged residual obtained from estimation of the long-run relationship and it represents the disequilibrium error term and ε_{it} is the error term for this OLS estimation at time t for country i. This is to test whether emissions from energy use Granger-cause FDI in the first regression and FDI Granger-cause emissions from energy use in the second regression for developing countries. Granger causality will be tested in two channels within an ECM. The first is to test for the hypothesis of no long run effect between the variables. In the second channel, the null hypothesis of whether the lagged changes of the explanatory variables and the coefficient of disequilibrium error term λ are jointly equal to zero is tested. i.e there is no Granger causality between the variables. The number of lags is chosen to be 2 to save degrees of freedom and the interpretation of data is at 5% level of significance [45,46].[3]

5. Empirical results

The estimation results of Eqs. (3) and (4) indicate that there is no long run effect between FDI and emissions from energy use in some of the countries. This is because out of 23 countries, λ is mutually significant in 7 countries only.[4] This shows that there is a two way relationship between FDI and emissions from energy use in these 7 countries. However, testing for the existence of no effect of the explanatory variable on the dependent variable in the long and short run jointly indicates that there is Granger causality between FDI and emissions from energy use that runs in both directions. A likely explanation for discrepancy in results is the short run interactions between the two variables or the heterogeneity within countries.

Having a closer look at the Granger causality results of Eqs. (3) and (4) in details, the coefficient of the lagged error term of short run disequilibrium is considered to represent the first channel of Granger causality. It has got the expected sign in all countries and it was significant in 15 countries in Eq. (3) and in 9 countries in Eq. (4).[5] This shows that emissions from energy use Granger-cause FDI inflows in 15 countries while FDI inflows Granger-cause emissions from energy use in 9 countries. Among these countries, 7 countries only showed evidence for a two way relationship between FDI inflows and emissions from energy use. This is because λ was significant in both equations for these countries.

[3] It is important to mention that saving degrees of freedom as a criteria for choice of the lag length is a procedure that is applied before in the literature as mentioned by Greene (2003, chapter 19, p.604) and Hayashi (2000, chapter 10, p.662).

[4] These countries are Bolivia, Chile, Costa Rica, Egypt, Honduras, Morocco and Venezuela.

[5] These countries are Algeria, Bolivia, Cameroon, Chile, Colombia, Costa Rica, Egypt, Guatemala, Honduras, Indonesia, Morocco, Philippines, South Africa, Tunisia and Venezuela for Eq. (3) and Bolivia, Chile, Costa Rica, Ecuador, Egypt, Honduras, Iran, Morocco and Venezuela for Eq. (4).

Table 2
Granger causality test results for developing countries (no long run effect) H_0: $\lambda_i = 0$.

Results	Number of countries
ENG Granger–cause FDI inflows	15
FDI inflows Granger–cause ENG	9
ENG Granger–cause FDI inflows and FDI inflows Granger–cause ENG	7
No long run effect	8 in Eq. (3), 14 in Eq. (4)

Table 3
Granger causality test results for developing countries[a].

Null Hypothesis	F-Statistic	Probability	Decision
ENG does not Granger–cause FDI inflows	2.983143	0.00000	Reject null
FDI inflows does not Granger–cause ENG	2.592029	0.00000	Reject null

[a] The results are for all coefficients jointly to test for Granger Causality in the short and long run in the case of a two period lags.

Table 2 shows the results for Granger causality from the first channel.

Examining the second channel for Granger Causality indicates the following: The null hypothesis of whether the lagged changes of the explanatory variables and the coefficient of disequilibrium error term λ are jointly equal to zero (no Granger causality between the variables) is rejected based on the F-test. This shows that there is Granger causality between FDI and emissions from energy use that runs in both directions when taking into account the short run and long run together. Table 3 shows summary of the results for Granger Causality from the second channel.

6. Conclusion and policy implications

This research conducted Granger causality test on the direction of relationship between FDI and emissions from energy use for developing countries. For that, a fixed effect panel data model with heterogonous slope was used. The sample studied included 23 developing countries over the period 1971–2010 and ECM was the chosen estimation approach. The estimation results for the first channel of Granger causality varied from one country to another. The results indicated that there is a two way relationship between FDI and emissions from energy use in 7 countries only. Furthermore, energy use emissions Granger-cause FDI in 15 countries, whereas FDI Granger-cause emissions from energy use in 9 countries. However, examining the second channel for Granger causality indicated the presence of a bidirectional relationship between FDI and emissions from energy use. A possible reason for this is the variations within countries or short run interactions between the two variables.

The estimation results highlighted that energy use emissions Granger-cause FDI in 15 countries out of the 23 countries studied. This goes in line with the pollution havens hypothesis. It shows that lax environmental laws proxied by emissions from energy use attract polluting FDI inflows to developing countries. This necessitates suggesting policy implications for these countries such as:

1. Imposing stringent environmental laws to decrease polluting FDI.
2. Avoiding broad statements in the law and presenting the needed specifications.

3. Avoiding individualistic decisions and adopting detailed guidelines for regulations to fight corruption.
4. Spreading public awareness of methods of preserving the environment, hazardous wastes effects and polluting firms. Public rating could be used to form a pressure on polluting firms.
5. Monitoring licensing of polluting industries such as cement, gypsum firms and foundries.
6. Giving more incentives to polluting firms to motivate them to abide by the legal emissions standards and to include the environmental factor with the economic factor in their decisions.
7. Carrying annual environmental assessment of firms to guarantee their commitment to the environmental objectives.
8. Imposing on new investment projects the incorporation of the social costs of environmental degradation among their total costs in their feasibility studies.
9. Replicating the new environmental techniques applied in developed countries.
10. One possible option here is applying a policy mix between different regulatory approaches such as command-and-control regulatory approach, economic incentives approach or non mandatory approach. In command-and control approach, the standards for pollution emissions and the methods to be used to reduce these emissions are decided upon by the government. In contrast to the economic incentive approach in which firms are free to decide on the suitable technique of production that guarantees meeting legal standards. In addition, firms are rewarded in case of producing below the legal standards. Lastly, non mandatory approach is related to the voluntary act of the firms to reduce their emissions level. Self-interest is the main cause behind such voluntary acts that can be, for instance, a reaction to the fear of loss of public acceptance in case of the disclosure of environmental information about the firms.
11. Ensuring enforcement and promoting various compliance methods. This is an important point to consider because environmental regulations may turn out to be unsuccessful if they are not enforced. Enforcement pushes polluting firms to comply with regulations. To this end, inspection, performance based contracts, compliance assistance and incentives are used.
12. Using clean energy sources instead of relying on fossil fuels and at the same time providing other sources of attraction to FDI in the form of economic or political stability, wider markets, cheap labor or even promotions such as tax breaks.

One policy implication deserves discussing thoroughly, which is the shift to clean energy sources instead of fossil fuels. Renewable energy sources are usually considered clean sources in contrast to non renewable sources which are often accused of emitting pollution. Renewable energy sources include solar energy, wind energy, falling and tidal energy, biomass sources and geothermal energy. Besides their reduction of pollution, renewable energy sources provide an economic stable source of energy. This stability arises from having a variety of alternatives of energy sources instead of heavily relying on oil and being vulnerable to its fluctuations whether in supply or prices [47]. Another advantage of renewable energy sources is that they depend mainly on local energy sources and hence, generate more jobs, increase export industries and foster economic development. In addition, renewable energy sources minimize costs of transmission and distribution as they could be easily located beside the site in use [47].

It is noteworthy to mention that renewable energy sources could have disadvantages as well. This can be in the form of emissions produced from biomass plants; the effect of wind farms on some birds′ survival and the effect of hydro projects on the ecosystems. Nevertheless, if compared to hazards of fossil fuels energy sources or that of nuclear energy, these disadvantages are less severe and more localized [47]. Accordingly, policies to promote the use of clean energy sources to replace fossil fuels include:

1. Applying a low-carbon economic model which is used in some cities of China [48]. Low-carbon economic model depends on achieving low pollution, low energy consumption and low emissions. This could be achieved through changing some of our consumption and production patterns to ensure that these goals are achieved. This entails spreading awareness among firms and the public of the importance of preserving our environment. Using fertilizer emission reduction projects, reducing carbon emissions from transportation and relying more on renewable energy sources are few among other possible paths to achieve a low carbon city.
2. Using renewable electricity standards (RES). This is applied by imposing on utility firms to get a specific percentage of their electricity from renewable sources.
3. Giving incentive in the form of tax reduction or subsidies to encourage investments in clean energy sources. Clean energy tax credit as suggested by the Union of concerned Scientists is a possible way.[6]
4. Taking the maximum benefit of energy use, energy intensity and energy efficiency relationship. That is to conduct careful studies on various markets/sectors to detect changes in their demand for energy use. Also, monitoring changes in energy intensity and analyzing its cause of change to judge on whether this is a true reflection of improvement in energy efficiency or it is just a behavioral or a structural effect. If this is the case, then encouraging energy efficiency to reduce energy costs through applying energy saving techniques and spreading awareness is essential.
5. Providing the needed infrastructure to facilitate and accommodate the targeted growth in renewable energy use.
6. Allowing easy access to renewable energy sources in markets at reasonable prices to encourage consumers and producers to rely on them.
7. Facilitating the shift to renewable energy sources in home utilities, restaurants and hospitals used for air conditions, heaters, ovens…etc by reducing the time and effort needed to accomplish the process. The Indian example of biomass fuel used for efficient and smokeless cooker in restaurants, schools, hospitals and temples is a successful story that should be studied and replicated [49].[7]
8. Spreading awareness among consumers to choose the environmental friendly source of energy.
9. Using programs like Energy Star, Energy Efficient Mortgage (EEM) and Modified Accelerated Cost Recovery System such as that applied in USA. In the Energy Star program, private lenders offer mortgages and finance to encourage consumers to buy Energy Star labeled goods that meet with the Environmental Protection Agency (EPA) criteria. The Energy Efficient Mortgage (EEM) is designed to support the residents to finance adopting clean energy sources in old or new houses. This is to give an additional benefit over the usual mortgage deal to efficient energy houses. Again, consumers eligible to such deals should abide by EPA criteria. Finally, Modified Accelerated Cost

[6] See ⟨http://ucsusa.org/clean_energy/smart-energy-solutions⟩.

[7] This effort was initiated by the Indian Energy and Resource Institute. For more details, visit ⟨http://www.myclimate.org/carbon-offset-projects/international-projects/detail/mycproject/15.htm⟩.

Table A1

	Level		First difference	
	Statistic	Prob.	Statistic	Prob.
A. Results of the augmented dicky fuller unit root tests in heterogeneous panel augmented dicky fuller-Fisher chi-square test with trend.				
FDI inflow	179.292	0	792.647	0
Energy use	55.8013	0.1525	449.217	0
B. Results of the Augmented Dicky Fuller Unit Root Tests in Heterogeneous PanelAugmented Dicky Fuller Choi Z-stat Test With Trend				
FDI inflow	−8.83258	0	−23.7077	0
Energy use	0.46640	0.6796	−17.2618	0

Table A2

	Level		First difference	
	Statistic	Prob.	Statistic	Prob.
A. Results of the Phillips–Perron unit root tests in heterogeneous panel PP–Fisher chi-square test with trend				
FDI Inflow	169.448	0	2738.05	0
Energy Use	47.9206	0.3948	527.34	0
B. Results of the Phillips–Perron unit root tests in heterogeneous panel PP–Choi Z-stat test with trend				
FDI inflow	−8.20041	0	−44.1512	0
Energy use	0.66868	0.7482	−19.6115	0

Recovery System enables the investors in solar, wind or geothermal property to enjoy depreciation deductions [50].

All in all, the use of clean energy sources, applying stringent environmental laws and increasing firms and public awareness about the importance of preserving the environment are vital for ensuring environmental sustainability in general and low levels of emissions in particular. Concerning FDI-environment relationship, FDI and emissions from energy use exhibit a two way relationship. However, the results of this research highlight the heterogeneity factor present in each country. Accordingly, it is recommended to study this relationship on individual country basis to have a clearer picture. In addition, focusing on industrial level will give a deeper dimension to the study. However, lack of disaggregated data is a constraint that faces researchers in many developing countries. Accordingly, governments and research centers should work hard to make data available.

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Appendix A. Unit Root Tests

See Appendix Tables A1 and A2.

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